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A Summary of Ecological Characteristics of the South Saskatchewan River Basin

With Specific Reference to the Bow River (1979 - 82)

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A SUMMARY OF ECOLOGICAL CHARACTERISTICS OF THE SOUTH SASKATCHEWAN RIVER BASIN WITH SPECIFIC REFERENCE TO THE BOW RIVER (1979 - 82)

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1.0 INTRODUCTION

The river ecological systems of the South Saskatchewan River Basin are highly dynamic because of the temperate nature of the climate. Riverine living (biotic) and non-living (abiotic) components of the ecosystems respond annually, seasonally and daily to a myriad of factors which interact with each other.

Charlton, Hamilton and Cross (1986), and Cross, Hamilton and Charlton (1986) prepared detailed limnological characteristics of the Bow, Oldman and South Saskatchewan rivers. These two reports are available from the Water Quality Control Branch, Pollution Control Division, Environmental Protection Services, Alberta Environment, Edmonton. The purpose of this report is to summarize these two reports with special reference to the Bow River. However, the temporal patterns documented are also representative for the Oldman and South Saskatchewan rivers.

1.1 The Bow River

The Bow River flows in a south-easterly direction from the Rocky Mountains near Banff, Alberta to the Oldman and South Saskatchewan rivers (Figure 1). It contributes 43% of the average annual surface water yield to the South Saskatchewan River, with the Oldman River contributing the remainder (Alberta Environment 1984).

Three major irrigation districts are located adjacent to the Bow River: the Western Irrigation District consisting of 76,029 assessed acres (500 farms), the Bow River Irrigation District consisting of

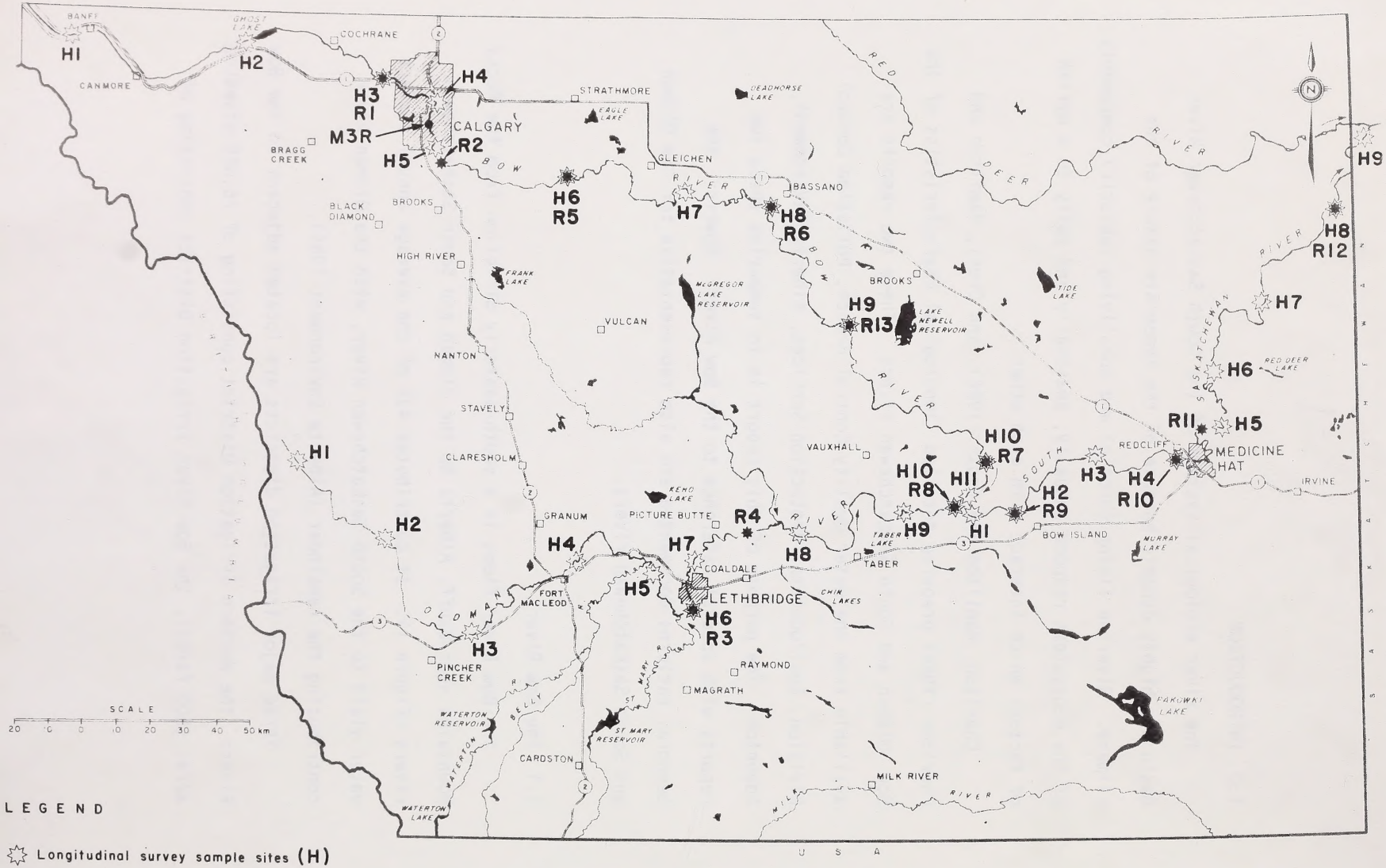

Figure 1. SOUTH SASKATCHEWAN RIVER BASIN

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164,889 assessed acres (750 farms), and the Eastern Irrigation District consisting of 229,110 assessed acres (1,150 farms). Water in the Bow River is used primarily for irrigation (95%), municipal supply (4%), and industry (1%). The Bow River is a particularly important fishery and recreational resource when compared to the Oldman and South Saskatchewan rivers.

Observations prior to the study period indicated that aquatic plants were particularly prolific downstream of Calgary. Their abundance led to clogging of water intakes and outlets, as well as interference with recreational water use (Exner 1977). Hence, a major study was initiated in 1979. The objectives of this study were to:

1. describe the biotic and abiotic characteristics of the Bow, Oldman and South Saskatchewan rivers;
2. discern the effects of the sewage treatment plant outflows upon the three rivers;
3. determine the factors which control the growth of nuisance aquatic plants throughout the basin.

1.2 River Discharge

One of the most important factors affecting the distribution and abundance of biotic and abiotic variables is river discharge volume. The principal source of river discharge is precipitation within the drainage basin. Another source of input to this river is groundwater.

Long-term records (1900 to 1982) indicate that the mean annual discharge for the Bow River at Calgary is 92.1 cubic metres per second (3250 cubic feet per second). Annual variations are, however, common because of the temperate nature of southern Alberta's climate. Figure 2 presents the annual patterns of discharge from 1970 to 1982. During 1972, 1974, 1976 and 1981, annual discharge exceeded the long-term average; however during the other nine years, annual discharge in the Bow River was below the long-term average. Below average discharge raised the concentration of nutrients because of lack of dilution, and reduced the scouring effects of average or above average river discharge.

The dilution and scouring effects of the Bow River are particularly profound during mountain snowmelt and runoff in June. During the remainder of the summer, flows generally decrease to winter minimums and groundwater then becomes increasingly important for the maintenance of river discharge. These patterns are similar in the Oldman and South Saskatchewan rivers.

1.3 Nutrients

Rivers carry the same dissolved and particulate inorganic and organic compounds and gases as those found in lakes; the chemical composition, however, is highly variable (depending on season, time of day, place and depth).

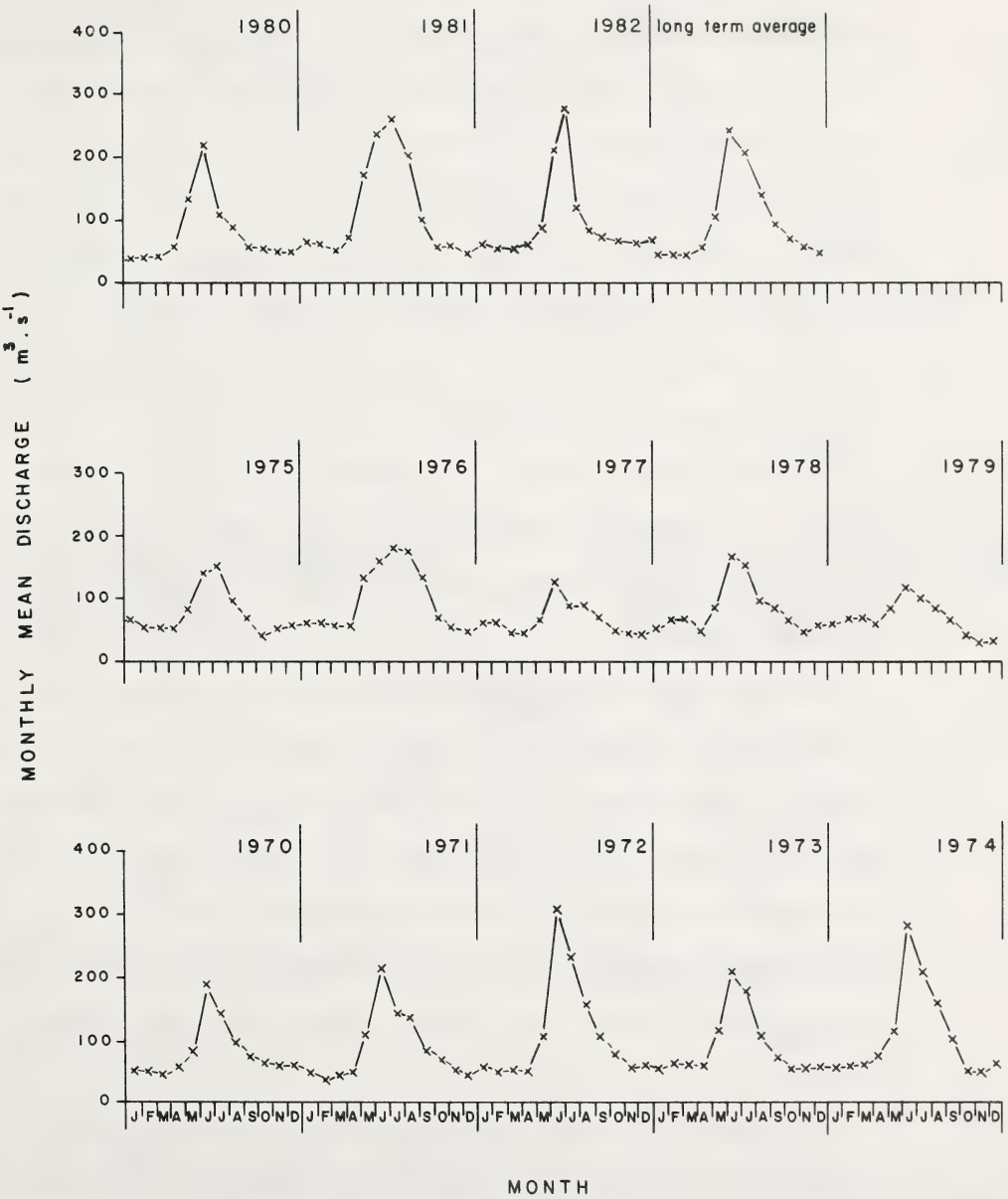

Figure 2. Monthly mean discharge in the Bow River at Calgary from 1970 to 1982.

As phosphorus and nitrogen are the primary nutrients which have been shown to stimulate the growth of aquatic plants (Wetzel 1975; Hamilton et al. 1981), these variables were studied in detail.

Cross et al. (1986) quantified the abundance and distribution of nitrogen and phosphorus in the Bow River in great detail. Hamilton et al. (1981) tested and evaluated algal growth potential for the Bow River. Dissolved phosphorus received particular attention since this is the form most readily utilized by aquatic plants.

1.3.1 Phosphorus and Nitrogen

The main natural source of phosphorus is erosion, and the chemical and mechanical weathering of rocks. Additional sources of phosphorus for the rivers include agricultural, municipal and industrial inputs.

Nitrogen enters the systems by erosion of both natural and artificially fertilized soils, rainfall, dustfall and algal nitrogen fixation. Agricultural, municipal and industrial inputs are also important sources of nitrogen. Therefore, a wide variety of factors contribute to the observed spatial and temporal variation of nitrogen and phosphorus concentrations. Both phosphorus and nitrogen follow similar seasonal trends (i.e., higher winter than summer values, Figure 3).

Phosphorus values for the Bow River are lowest upstream of Calgary (0.003 - 0.018 $mg \cdot L^{-1}$) and highest immediately downstream of

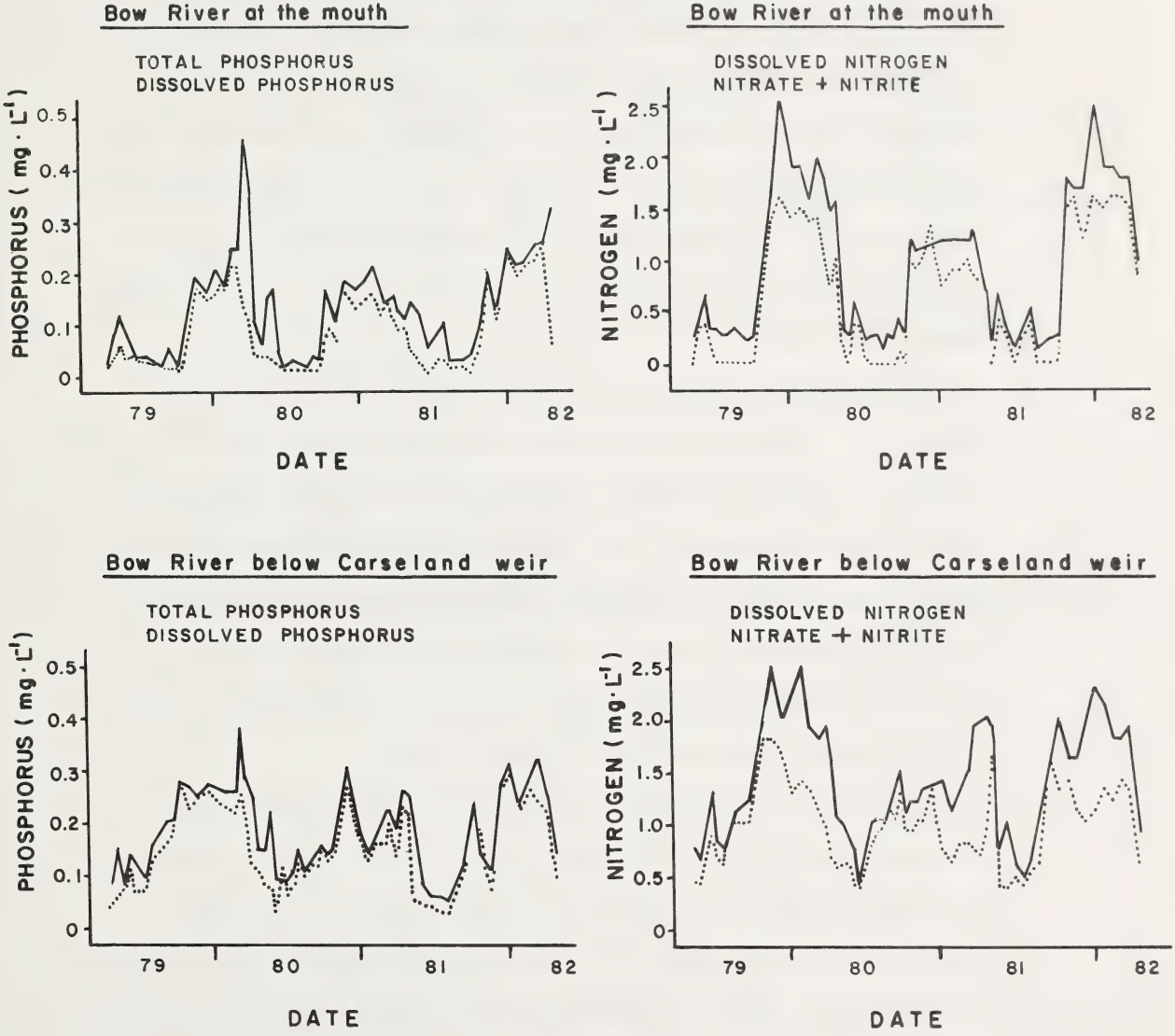

Figure 3. The temporal changes of phosphorus (total and dissolved) and nitrogen (dissolved and nitrate + nitrite) for the Bow River at Carseland and Site 7 near the mouth.

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Calgary (0.430 - 0.800 $mg \cdot L^{-1}$). Total phosphorus concentrations decrease at each successive site downstream of Calgary, ranging from 0.042 $mg \cdot L^{-1}$ in summer to 0.202 $mg \cdot L^{-1}$ in winter at Site R7. Dissolved phosphorus undergoes similar spatial trends but since this form is utilized by the aquatic plants, it increases and decreases in response to plant uptake. That is, dissolved phosphorus is taken up by aquatic plants during the growing season and then released in the autumn when they die.

Upstream of Calgary, dissolved phosphorus represents a small component of the total phosphorus measured in the Bow River. This is altered at Calgary by inputs of treated sewage effluent that are high in dissolved phosphorus. The primary source of dissolved phosphorus to the Bow River is the City of Calgary which contributes 91% of the dissolved phosphorus loading. Upstream sources contribute 2%. Dissolved phosphorus provides 90-97% of the total phosphorus loading from the sewage treatment facility to the river.

A comparison of historical (1970-79) dissolved phosphorus and nitrogen values for the Bow River at Site R7, upstream of the mouth is presented in Table 1. During 1980 through 1982, mean dissolved phosphorus concentrations in the Bow River were higher than historical concentrations, especially during the spring and winter. Conversely, recent mean nitrogen concentrations (1980-82) were often less than historical values. This means that the Bow River has not been subjected to continually higher nitrogen and phosphorus concentrations during all seasons of recent years (1980-82) when compared to historical information.

TABLE 1. Comparison of study data and historical data (1970 to 1979) for selected nutrient parameters.

	MEAN DISSOLVED PHOSPHORUS $mg \cdot L^{-1}$		MEAN DISSOLVED NITROGEN $mg \cdot L^{-1}$		MEAN NITRATE + NITRITE NITROGEN $mg \cdot L^{-1}$	
	1980-82	1970-79	1980-82	1970-79	1980-82	1970-79
SITE 7						
Annual	0.082	0.067	0.95	0.98	0.64	0.73
Spring	0.082	0.058	0.84	1.15	0.54	0.57
Summer	0.025	0.019	0.31	0.27	0.08	0.07
Fall	0.044	0.041	0.81	0.76	0.57	0.76
Winter	0.166	0.121	1.84	1.35	1.29	1.00

1.4 Temperature

In addition to the temporal variation of nutrients, temperature also changes seasonally and diurnally. River temperatures reach a maximum during August, frequently in the mid 20°C range. Diurnal and seasonal temperatures are influenced primarily by climate and flow regime as well as by numerous other factors which influence the heat absorbing quality of the water. The presence of structures or aquatic plants may, for example, impede or retard the flow of water and result in higher ambient water temperatures.

1.5 Aquatic Vegetation

The vegetation of a river is typically an unstable, complex mosaic of species. It varies continuously from reach to reach and from time to time, and often differs between similar reaches in neighboring rivers (Whitton 1975).

Submerged macrophytes in general have access to nutrients through their leaves as well as from their roots (Whitton 1975). Algae form another community. Algae adhere to all surfaces including the macrophytes. Both of these communities utilize light, hence they may compete for both light and space. Algae are extremely opportunistic. They have a relatively short lifespan and a capacity to grow under low light conditions. Therefore, aquatic vegetation may flourish throughout the system, although not always forming large, recognizable nuisance growths.

1.5.1 Macrophytes

Macrophytes are large, obvious water plants. They die off during the autumn and persist as seeds, sprouts and root-like stems. Macrophytes grow rapidly during the spring and reach their maximum biomass in late summer. The exact time of the maximum is dependent on the species, the weather and the hydrological regime. Rhizomes (underground storage organs) are particularly important sources of new plants each year. These structures, which resemble large thickened roots, are rich in starch. They remain in the subterranean habitat (in the river bed) throughout the fall and winter, and produce new plants the following year. Unlike the algae, the macrophytes are perennial.

Because of their reproductive success in the enriched river zones near Calgary, the macrophytes modify the hydrological regime as well as the physical and chemical characteristics of the Bow River. Dense strands of Potamogeton vaginatus, P. crispus, P. pectinatus and Zannichellia palustris absorb large amounts of phosphorus, retard the flow of water, cause siltation, and shade the substrate. They compete with the microscopic benthic algae for nutrients, space and light.

Macrophytes also exhibit spatial variation in relation to the availability of dissolved phosphorus. Investigation of the biomass at right and left bank locations immediately downstream of the Bonnybrook sewage treatment plant indicated much higher standing crops along the right bank (Figure 4). This coincided with enrichment from municipal discharges . Standing crops were lower on the left bank and

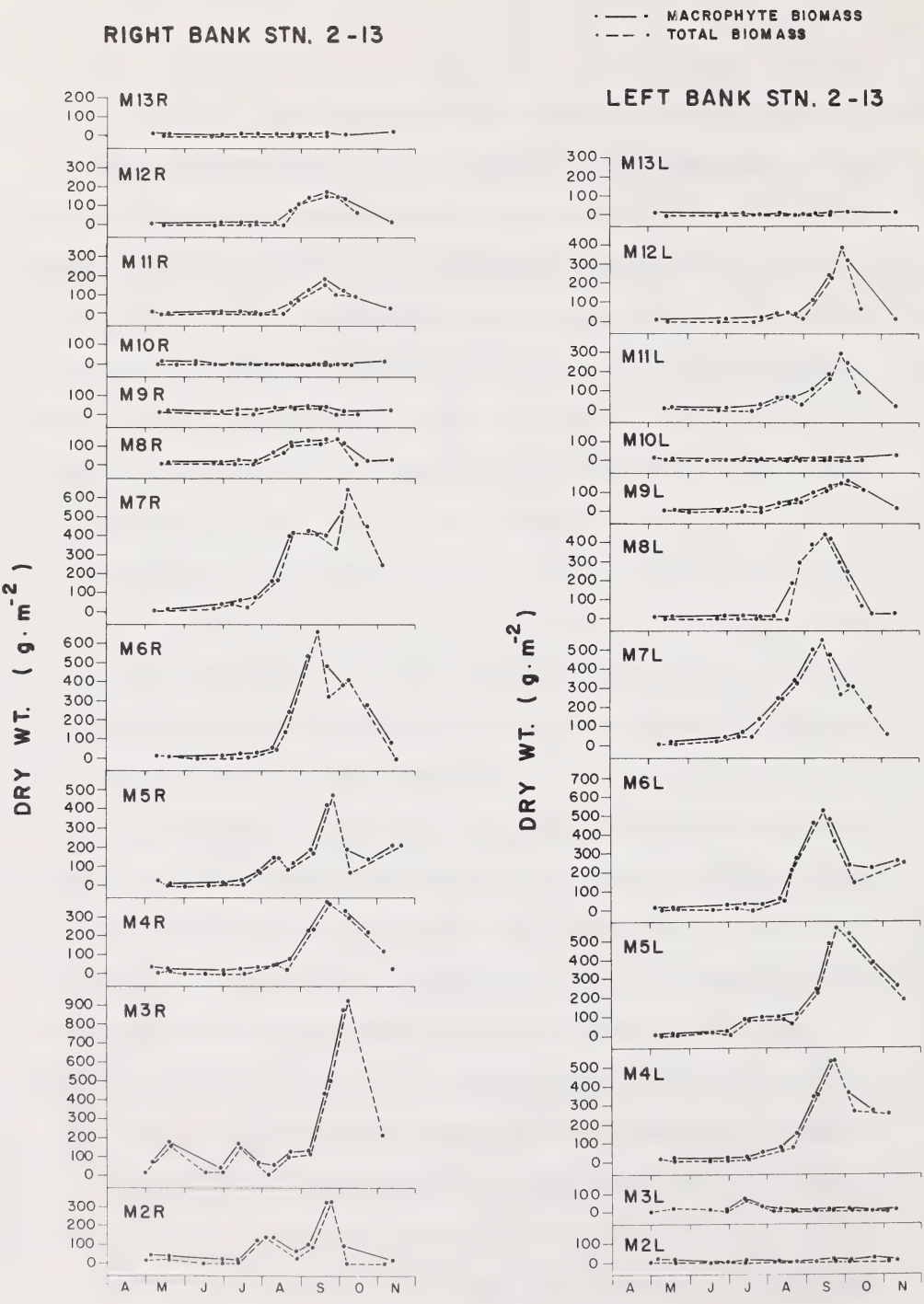

Figure 4. The seasonal variation of macrophyte and macrophyte + algal (total) biomass for 1981 in the Bow River.

responded less quickly to municipal discharge due to the lack of transverse mixing in the vicinity immediately downstream of the Bonnybrook sewage treatment plant.

The relationships between macrophyte biomass, depth and velocity were examined among all sites (Charlton et al. 1986). The findings for an exemplary site (M3R) are presented in Figure 5. River velocities between 1.4 $m \cdot s^{-1}$ and 1.8 $m \cdot s^{-1}$ (metres per second) were found to represent a critical range beyond which macrophyte tissue was scoured from the river bottom. Standing crops frequently exceeded 1000 $gm \cdot m^{-2}$ (dry weight) in the zone of prolific macrophyte development during late summer. High macrophyte biomass occurred in the river regions where dissolved phosphorus exceeded 0.010 $mg \cdot L^{-1}$, but the biomass was negligible where concentrations were less than 0.005 $mg \cdot L^{-1}$.

1.5.2 The Algae

The algae are the most diverse component of river primary producer communities. They occur not only in the water column (phytoplankton), but also attached to virtually every submerged object and plant. The community found growing attached to rocks (epilithic) are particularly important sources of food for numerous other components of the food chain.

Charlton, Hamilton, and Cross (1986) investigated the seasonal dynamics of phytoplankton and epilithic algal standing crop, species composition and carbon uptake (primary productivity). Evidence was provided showing blue-green algae (Cyanophyceae), diatoms

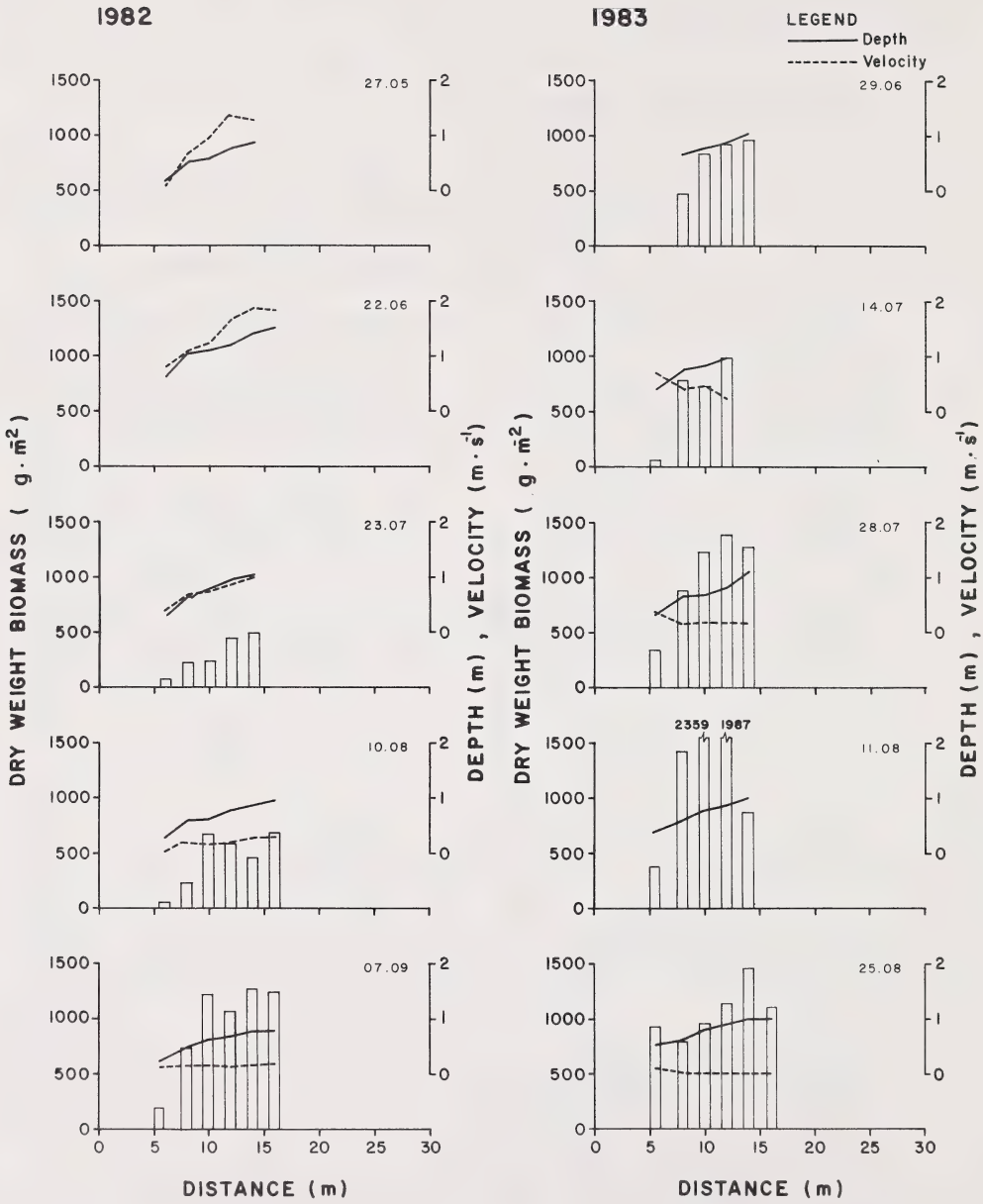

Figure 5. Macrophyte biomass in relation to depth and velocity at Site M3R, downstream of Calgary.

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(Bacillariophyceae) and green algae (Chlorophyceae) were the dominant algae, respectively. The algal numbers in each of the major algal taxonomic divisions increase or decrease in response to the physical and chemical characteristics of the river. Dominance by one or the other is a function of the capacity to utilize the resources available. For example, diatoms tended to dominate during the colder water periods, while blue-green and green algae were generally more abundant during the warm water periods.

Epilithic algal standing crops were estimated both numerically and by determination of the amount of chlorophyll a present. Standing crop estimates during 1980 to 1983 ranged from 3 to 439 mg chlorophyll $a \cdot m^{-2}$ (mg of chlorophyll a per square metre). The highest mean standing crop was found at Carseland (Site R5) (296 mg chlorophyll $a \cdot m^{-2}$) and the lowest at Bowness (Site R1) located upstream of Calgary (31 mg chlorophyll $a \cdot m^{-2}$). The distribution and abundance of epilithic algae was highly correlated with the abundance of phosphorus and nitrogen. Epilithic algal standing crops were highest in the river regions downstream of nutrient sources and outside of those river regions where macrophytes had a competitive advantage (Charlton et al. 1986).

Figure 6 presents the variation of algal standing crops and nutrients in the Bow and South Saskathewan rivers. Algal standing crops in the Bow River are highest between the Elbow River tributary and Bow City. Nutrient concentrations are similarly highest in this river region, indicating further the stimulatory effects of nutrient inputs upon aquatic plants.

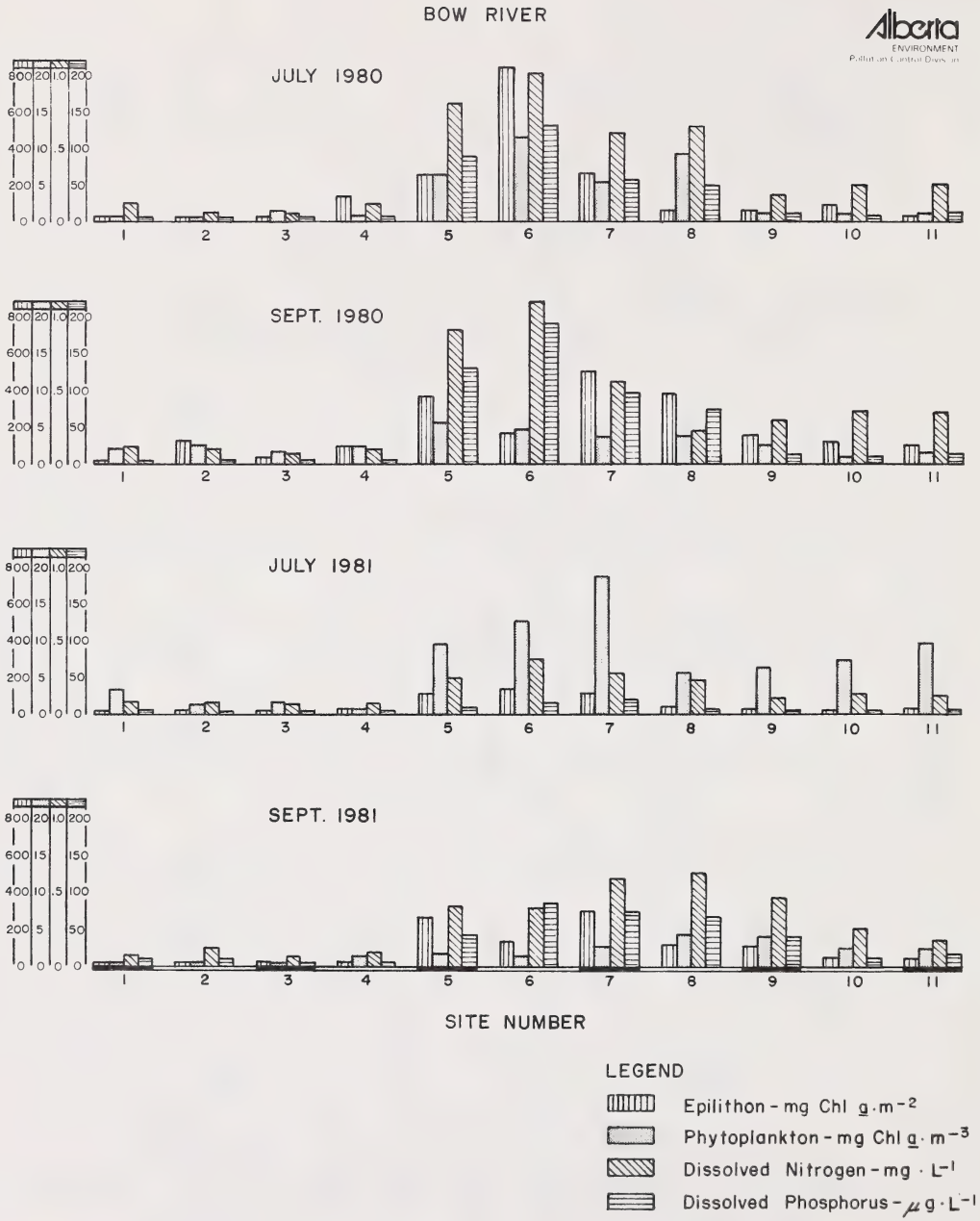

Figure 6. River course variation of algal standing crops, dissolved nitrogen and dissolved phosphorus from the Bow River headwaters (Site 1) to it's confluence with the Oldman River (Site 11).

Although chlorophyll a provides an estimate of algal standing crop, this measurement is not entirely indicative of the photosynthetic activity occurring in a river. Epilithic algae incorporate carbon at rates which vary in response to the standing crop and physiological state of the algae. In the Bow River during 1980/81 the rate of carbon uptake was highest, on average, at Carseland (i.e., 179 mg carbon $\cdot m^{-2} \cdot h^{-1}$ or mg carbon per square metre per hour). Values for the entire Bow River ranged from a minimum of 1 mg carbon $\cdot m^{-2} \cdot h^{-1}$ at Ronalane Bridge near the mouth of the river to 583 mg carbon $\cdot m^{-2} \cdot h^{-1}$ at Carseland. The lowest mean rate of carbon uptake was found at Bowness, immediately upstream of Calgary.

Charlton et al. (1986) also provided evidence that primary production was much higher during 1980 than 1981. As noted earlier, 1981 was an above average discharge year, and the epilithic algae were subjected to lower nutrient concentrations (dilution effects) and greater abrasive forces. These factors have also been shown to be paramount with regard to epilithic algal productivity and standing crop among other Alberta rivers (Charlton 1986).

Epilithic algal primary production (carbon uptake) varies not only seasonally and annually but also diurnally. Plants incorporate nutrients specifically at rates which vary in response to light, which in turn is one of the primary factors affecting photosynthesis. Figure 7 presents the diurnal pattern of algal photosynthetic efficiency and some related physical factors. Epilithic algae in the Bow River are most efficient between 0600 and 1600 hrs (MST).

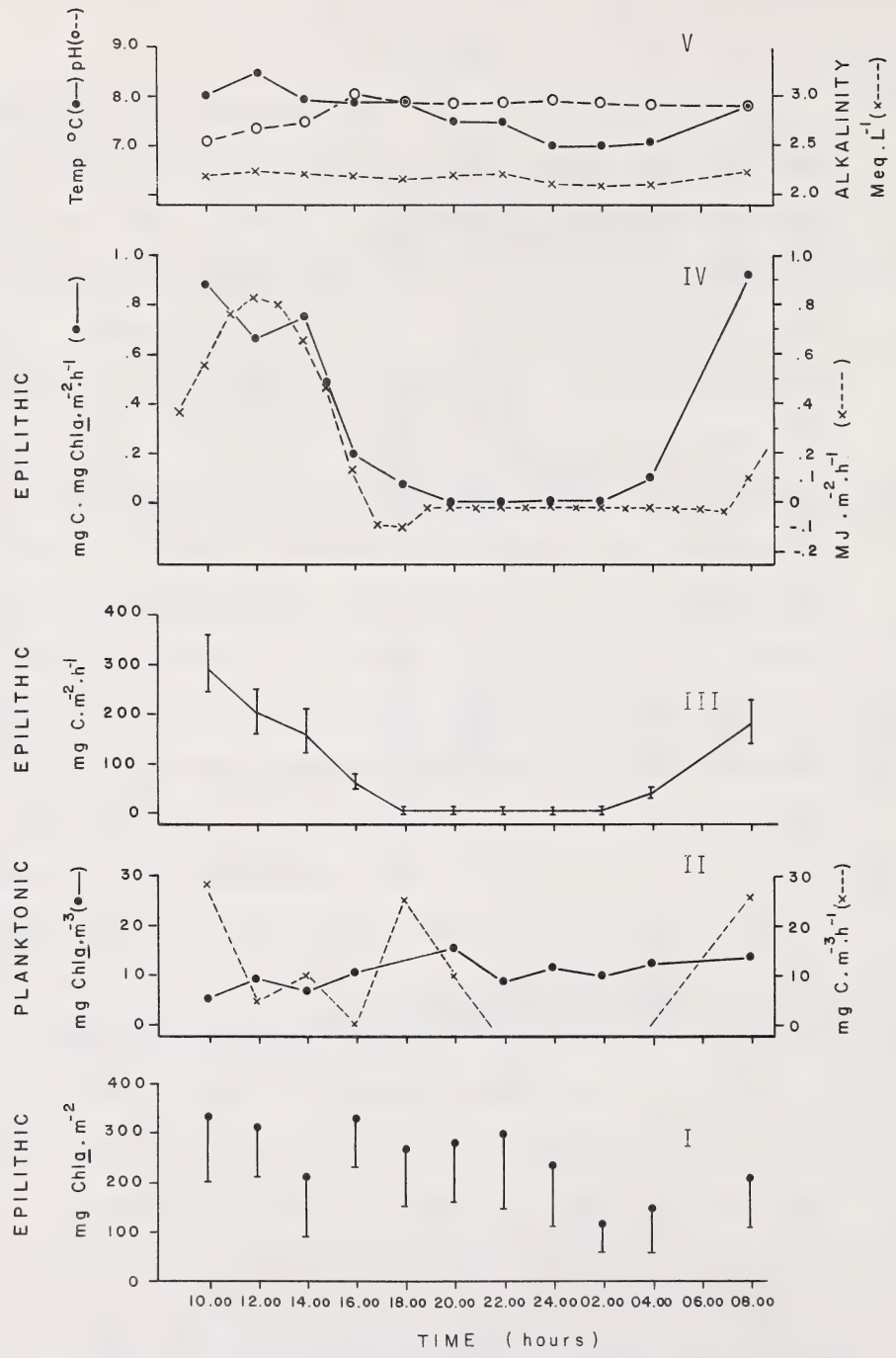

Figure 7. Diurnal variation measurements at Site R5 of :

I. Epilithic Chlorophyll a
II. Planktonic Chlorophyll a
III. Epilithic primary productivity
IV. Epilithic photosynthetic efficiency
V. pH, temperature, and bicarbonate alkalinity

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Moreover, photosynthesis undergoes a mid-day suppression that is attributed to the reduced reflection of sunlight at mid-day. The highly variable nature of photosynthetic efficiency and the dissimilarity between epilithic and planktonic algal productivity is presented in Figure 7. Epilithic primary productivity increases and decreases in response to the available solar radiation (heat and light) while planktonic production responds more to light and other physical factors.

Algal biomass and productivity, as well as macrophyte biomass, exhibit spatial and temporal patterns. Their distribution and abundance is highly correlated with phosphorus, nitrogen and discharge.

A very important factor affecting algae and macrophytes in the Bow River is discharge. The spring flood specifically scrapes off the algae and surface biomass of macrophytes. Underground reproductive structures (rhizomes) of macrophytes, however, are rarely eroded from the river bed. Hence, from year to year, macrophytes reappear in the same river regions downstream of Calgary. Moreover, the uptake and storage of large amounts of nutrients increases their residence time in specific river regions. Macrophytes and algae mobilize appreciable amounts of nutrients by absorption from sediments, hence, it would appear that only time will prove or disprove the effectiveness of nutrient reductions in municipal effluents as a method for reducing aquatic plant standing crops.

1.6 Summary

Charlton et al. (1986) provided evidence that the factors which control the distribution and abundance in aquatic plants in the Bow River are phosphorus, discharge and temperature. Discharge and discharge-related factors scour the macrophytes at velocities in excess of 1.0 $m \cdot s^{-1}$. Light ranging from 600-2000 footcandles, velocities ranging from 0 to 0.40 $m \cdot s^{-1}$ and dissolved phosphorus concentrations exceeding 0.010 $mg \cdot L^{-1}$ provide optimum growing conditions in the Bow River downstream of Calgary.

Although the spring flood frequently abrades the algae and surface biomass of macrophytes, it does not erode the reproductive structures (rhizomes) of the macrophytes buried in the river bed. Hence, from year to year, macrophytes reappear in the same river regions downstream of Calgary. Algae, on the other hand, are extremely opportunistic, and they are invariably replaced by upstream sources. The uptake and storage of large amounts of nutrients by aquatic plants, particularly macrophytes, increases the residence time of the nutrients and minerals within a given reach of stream. Macrophytes mobilize appreciable amounts of nutrients by uptake from sediments and absorption from the water. Thus, the future of macrophyte biomass depends upon not only the physical condition of the river, but also the chemical make-up of the river water and sediment.

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